Empirical Modelling for Educational Technology

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Contexts for personal observation

Refer to a situation in which observables, dependency and agency are perceived as a **context**

many contexts typically interleave and overlap in the stream of consciousness

Identifying contexts is itself an imprecise and empirical process

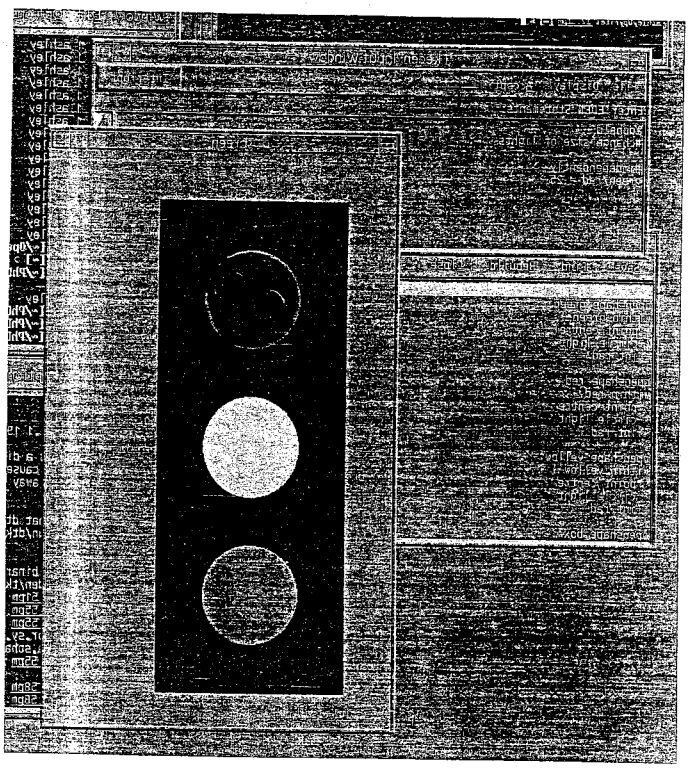
concentration is associated with focus upon a particular context

contexts have intrinsic integrity and continuity, but can be suspended and resumed

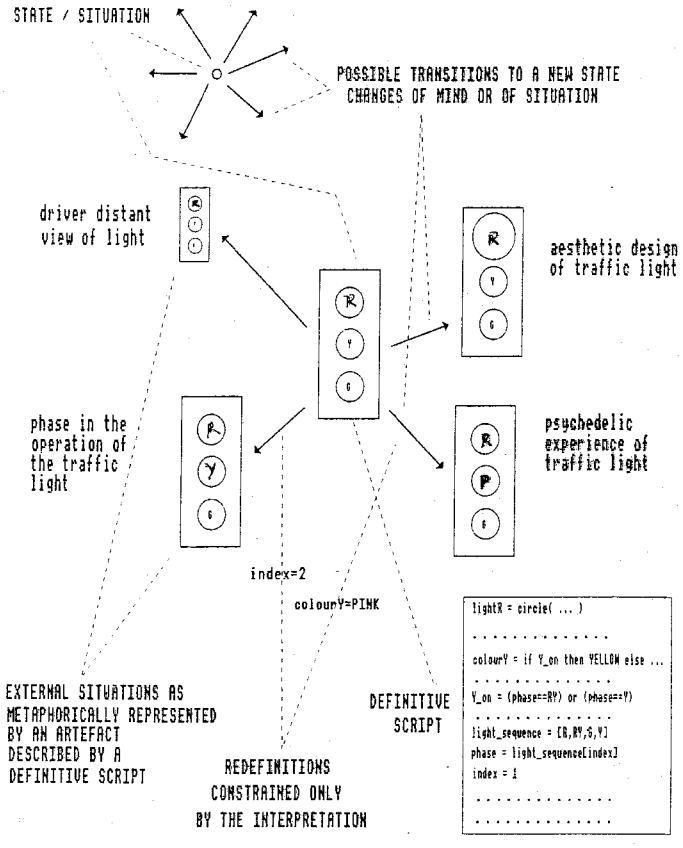
Experiences drawn from one context can be appropriated to another, cf:

- use of artefacts
- development of instruments
- development of skills
- activities such as "blending"

Contexts are to some extent associated with roles I can play, and be deemed to be playing simultaneously



1-Agent Modelling



An illustrative example

Different roles in which I can observe a traffic light

Traffic light designer (aesthetic) *agent*

shape, location, colour, size of lights *observables*

Driver at road junction

colour pattern, phase of lights, traffic convention

Traffic light installer

time delays in cycle, traffic sensors, visibility in context

Traffic light maintenance

electrical components, voltages, currents, resistances

Mere observer: dog owner, poet, short-sighted, hallucinating

effects of sunset, shadow, poetic interpretations
traffic light as lollipop, as tower of faces, coloured blobs

Objective observer: a traffic police monitor

speeds and locations of cars
synchronisation of car motion and light status

The use of a Definitive Script ("script of definitions") to represent state

Conflate many perspectives on traffic lights, & represent using a family of definitions

```
# typical definition:    observable = function of observables

# Traffic light designer (aesthetic)
shape                    lightR = circle(centreR, radiusR)
                         lightY = circle(centreY, radiusY)
                         lightG = circle(centreG, radiusG)
location                 centreR = (x,y)
                         centreY = (x, y-k)
                         ...
colour                   colourR = if red_on then RED else DARK
                         ...
size                     radiusR = 10 inches
                         ...

# Driver at road junction
colour pattern           red_on = if (phase is R or RY) then R_on else R_off
                         yellow_on = if (phase is RY or Y) then Y_on else Y_off
                         ....
phase of lights          light_sequence = [R, RY, G, Y]
                         phase = light_sequence[index]
index (in range 1..4)    index =  1

traffic convention
                  status = ["stop", "ready to go", "go", "ready to stop"][index]

# Traffic light maintenance
electrical components    bulbR = OK
                         ...
                         power = ON
voltages (in volts)      voltageR = if (power == ON) then 240 else 0
                         ....
currents (in amps)       currentR = voltageR / resistanceR
                         ....
resistances (in ohms)    resistanceR = if bulbOK then K else infinite
                         ....
status of components     R_on = (bulbR==OK) and (power==ON)
                         ....
```


Representation of roles

Sometimes appropriate to conflate observables from several different roles

For instance, I may be a traffic light repair man who happens to be a short-sighted driver approaching a traffic light that is malfunctioning

Conflation of contexts is potentially a creative process e.g. essential to explanation of interaction

... parable conveniently combines story and projection. To understand parable is to understand root capacities of the everyday mind, and conversely.

Meanings ... are not mental objects bounded in conceptual spaces but rather complex operations of projecting, blending, and integrating over multiple spaces.
Mark Turner: The Literary Mind (p5, p86)

For a causal account of what is being observed in relation to the traffic light, also need **separation of roles**

e.g. what are the driver's responsibilities? what expectations have we of a driver?

Identify roles through the classification of observables (using **the LSD notation**)

oracles those observables that properly belong to my current role

as a driver, I am concerned with the pattern of colours
as an aesthetic designer, I am concerned with the colours

handles those observables over which I have conditional control

as an aesthetic designer, I can influence light colour, size, location

derivates those indivisible patterns of correlated change I observe

a driver expects the light pattern to reflect the phase indivisibly
an aesthetic designer switches the lights randomly & independently

protocol rules that connect observed cues for action with potential response

too brief a green light for heavy traffic: cue for a traffic light installer to increase the length of the green light in the light cycle

Causal accounts: introducing the 2nd person perspective

Contexts are organised around collections of observables that have integrity

In giving a causal account of a phenomenon in a context, am led to postulate agency similar to my own

See agents as mediating, and being explicable in terms of projection of agency "resembling my own"

The coherence of my interaction empirically validates the identification and projection of agency

Conceive the traffic light itself as an agent: responding to its environment;

```
agent traffic light {

oracle      time_elapsed, time, car_waiting, phase

state       phase (R, RY, G, Y)
            red_lit, yellow_lit, green_lit
            time_on_R, time_on_G, time_in_transition
            time_of_last_change

derivate    red_lit = (phase==R) or (phase==RY)
            yellow_lit = (phase==RY) or (phase==Y)
            green_lit = (phase==G)
            time_elapsed = time - time_of_last_change

protocol    (phase==R) and car_waiting and time_elapsed > time_on_R
                        -> time_of_last_change =|time|; phase=RY,
            (phase==RY) and time_elapsed > time_in_transition
                        -> time_of_last_change = |time|; phase=G,
            (phase==Y) and time_elapsed > time_in_transition
                        -> time_of_last_change = |time|; phase=R,
            (phase==G) and time_elapsed > time_on_G
                        -> time_of_last_change =|time|; phase=R
}
```

Metaphorically, it is *as if* a traffic light knows the time, knows the current phase of the lights, and can detect whether there is a car waiting etc etc

Status of the Model of the Traffic Light

Observables include quantities that can't be directly observed

E.g. the behaviour of a traffic light is attributed to voltages, currents etc of which I have no experience

use artefacts (like animated circuit diagrams) to tell me how a traffic light operates and instruments (like voltmeters) to create experiential equivalents of putative conceptual quantities

Empirical evidence is enough justification for adopting a particular explanation
This explanation is effectively captured in an LSD account of the traffic light

The information about observables can be partial e.g. car_waiting is at a high level of abstraction e.g. might be supplied by an optical sensor or switch in road

```
agent switch_in_road {
oracle      car_crosses_switch, time
state       car_waiting, time_to_clear_lights, time_crosses_switch
derivate    elapsed_time = time - time_crosses_switch
protocol    car_crosses_switch
                -> car_waiting = true; time_crosses_switch=|time|,
            elapsed_time > time_to_clear_lights -> car_waiting=false
}
```

This raises behavioural issues e.g. can car_waiting be set to false when there is no possibility of crossing the switch?

Modelling activity prompts speculation about scenarios that are not preconceived

Can't usually automate from an LSD account: conflicts, ambiguities to be resolved

Execute protocols under super-agent control / entirely under super-agent discretion

Reflects the extent to which implicit representation of ignorance is involved
What we *have* experienced shapes our expectations about what we haven't

Closed-world modelling is typically optimised to exploit what has been experienced

Use model to identify contexts, agents, dependencies, and to formulate hypotheses

Communicating from myself to another agent like myself

Empirical Modelling identifies the primitive with 1st person activities: I assert that
"this experience is like this experience"
No-one else can experience this likeness as I experience it in the sense that my experience is divorced from your consciousness and vice versa

[cf the idea that logic provides the most primitive foundation for human activity]

There may be what empirically seems to be a corresponding likeness between two experiences of your own

I may construct an artefact specifically to represent some experience in this manner

It may be that this artefact serves a mediating role in leading you to apprehend what empirically seems to be a similar likeness between your own experiences

Personal validity of my use of artefacts to represent experiences doesn't rely on this

e.g. snooker player uses an idiosyncratic trick to align the cue for a particular shot

Mediation needn't be via a commonly perceived artefact, e.g. invoked linguistically

cf "though I sang in my chains like the sea"

... where words evoke the likeness *but* two private experiences are necessary for the likeness to be apprehended

"singing in chains" as sense of protesting against being captive
"the sea singing in chains" as evoking breaking waves over pebbles

Communication between observers introduces intersubjectivity issues

cf the commonly accepted different nature of certain observables, such as traffic speed readings

cf the way in which mathematical models e.g. finite state machines, geometric references are used

Motivations for Empirical Modelling

Investigation of blends

Explanatory modelling, especially where conflict is involved (e.g. accidents)

Identification of stable contexts

Designing behaviours for concurrent systems of agents

Supporting activities in which concurrent decision-making is involved

Enabling construction through experimentation and human intervention

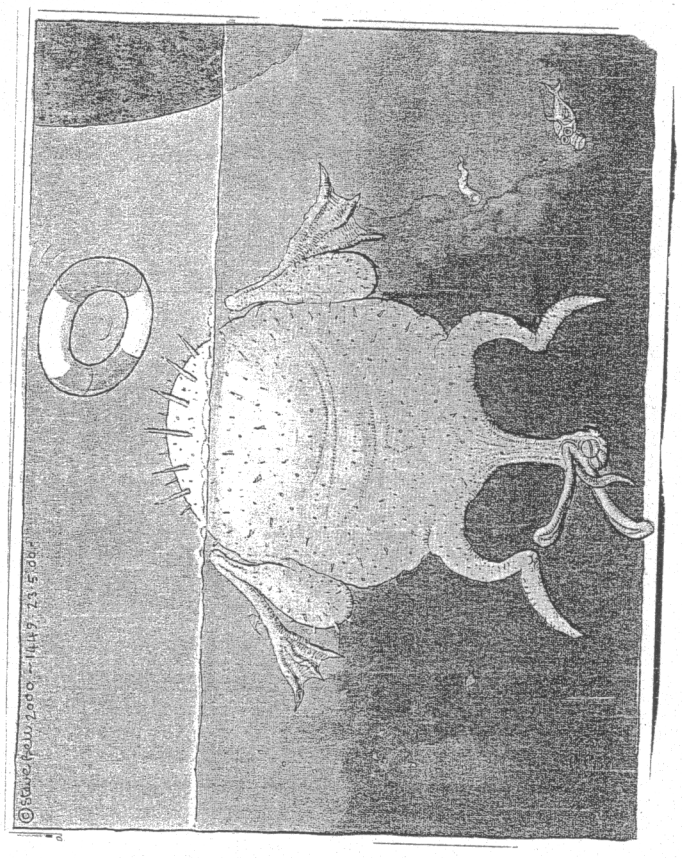
Migration through different paradigms of knowledge represented in the Empiricist Perspective on Learning

Ways in which to organise and interpret the use of definitive scripts

A. 1-agent modelling

B. Modelling the interaction of many agents in a concurrent system

C. Modelling phenomena from several different perspectives concurrently



Ways in which to organise and interpret the use of definitive scripts

A. 1-agent modelling

I act as a single agent, conflating roles, slipping in and out of roles
No adherence to a single context, nor need to reflect an external situation.
Gives scope for experimentation, creative processes, fantasising.
Transitions from script to script are unconstrained, and I have arbitrary privileges

Also use 1-agent modelling to study particular roles in detail (such as driving past traffic lights) subject to realism (cf VR), and the creation of convincing artefacts.

B. Modelling the interaction of many agents in a concurrent system

I create a script as an external observer of the interactions between many agents.

Explanatory modelling, as in science or as in accident investigation involves projection of presumed states on to other agents.
Issues: stimulus-response patterns, time-based behaviour, synchronisation.
Simultaneous redefinition of observables is possible.

Typically the transitions from script to script will presume a particular context
Integrity to guarantee there is a system, system analysis prescribes observations.
cf the role of the traffic police monitor

External observer may exercise complete discretion over state transitions:

- to play the roles of the agents within the system
  e.g. I might take on the role of changing the traffic lights
- to arbitrate where the outcome of singular events is uncertain
  e.g. I might decide what outcome to presume where two cars collide
- to simulate failures and malfunction of the system
  e.g. I might explore the effect of lights failure, or speedier changes
- to carry out controlled experiments, possibly on subcomponents
  e.g. to assess reasonable stopping distances in bad weather.

Ways in which to organise and interpret the use of definitive scripts (cont.)

C. Modelling phenomena from several different perspectives concurrently

The modelling activity is carried out in a distributed environment
i.e. different agent roles for traffic lights represented by scripts on different w/s's.

Can use for the idiosyncratic observer who is not "in touch with reality".

The most significant aspect of this modelling activity is the management of views.
This can serve many functions:

- to make many designer's perspectives coherent (concurrent engineering)
- as a forum for discussion between viewpoints (dialectic)
- as a framework for integrating private and public activities
- as a setting for studying administrative strategies and business processes
- to represent a diversity of different viewpoints (post-modernism).

(3)

Principles of Empirical Modelling

Elaborate a model of a phenomenon with reference to a projected causal account ...

Involves systematic identification of

observables

patterns of correlated change to observables ("indivisible relationships")

agents as instigators of state-change

observables that are presumed to account for stimulus-response patterns in agent interaction and their classification with respect to each agent

Leads to the construction of behavioural models, in general partially under super-agent control.

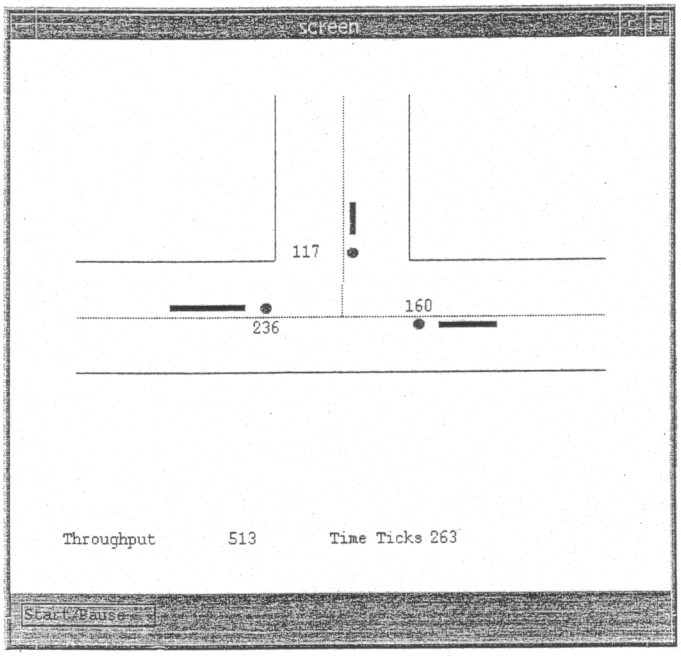
N.B. A single model incorporates an uncircumscribed family of open and closed behaviours

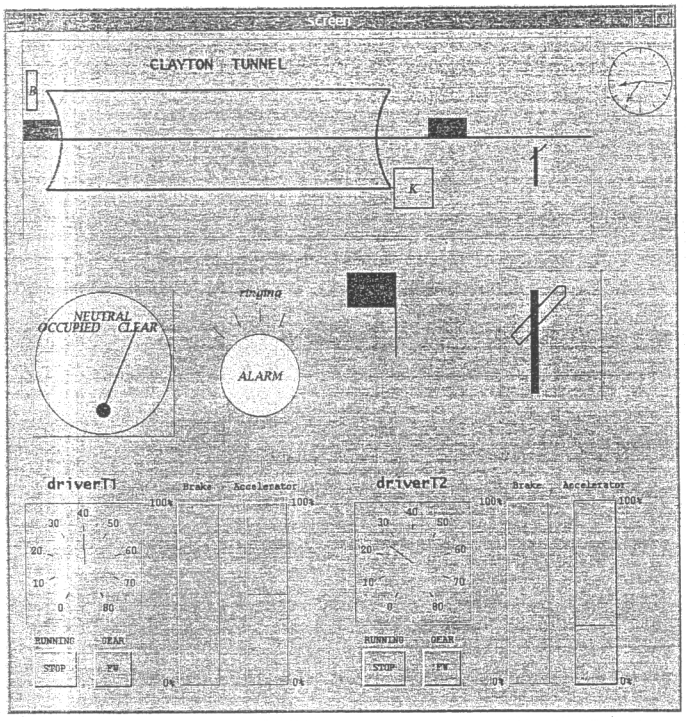
These include:

experimental environments

incomplete models from early stages of development

intrinsic behaviours associated with automatic agents

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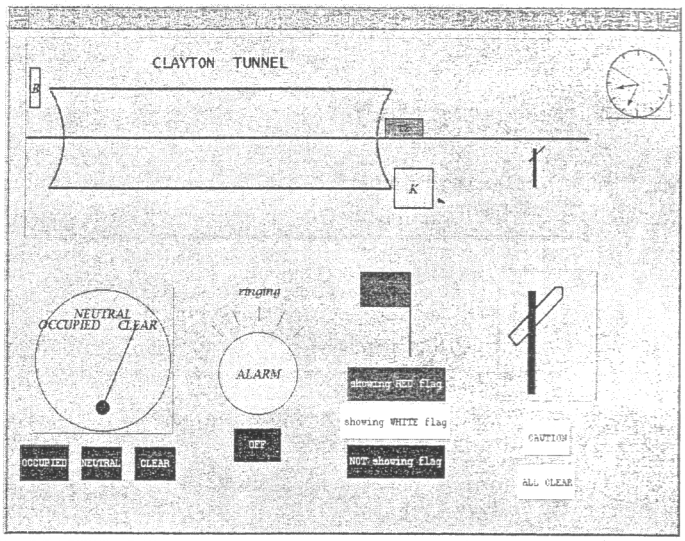
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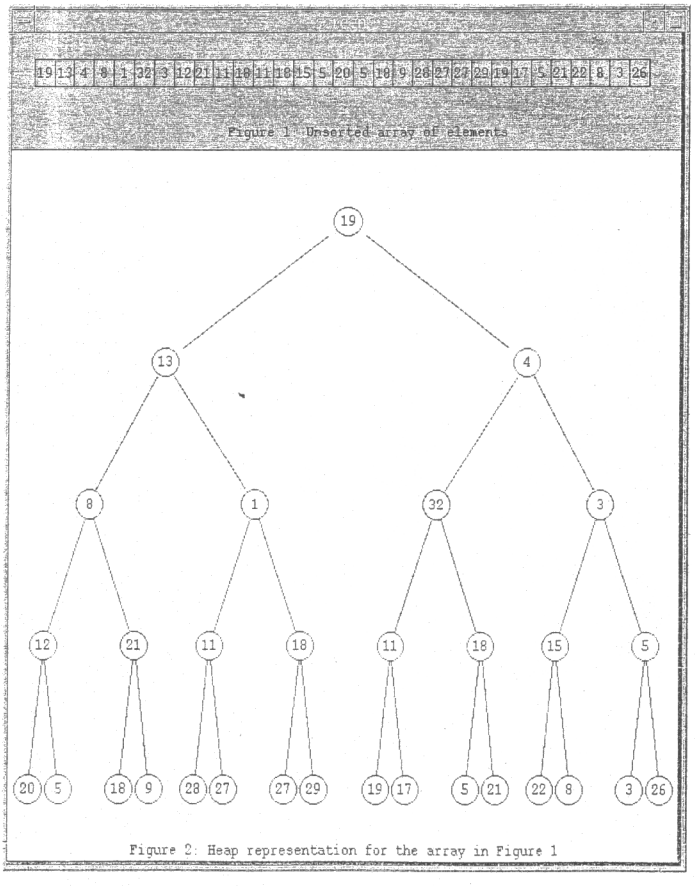
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Figure 1: Unsorted array of elements
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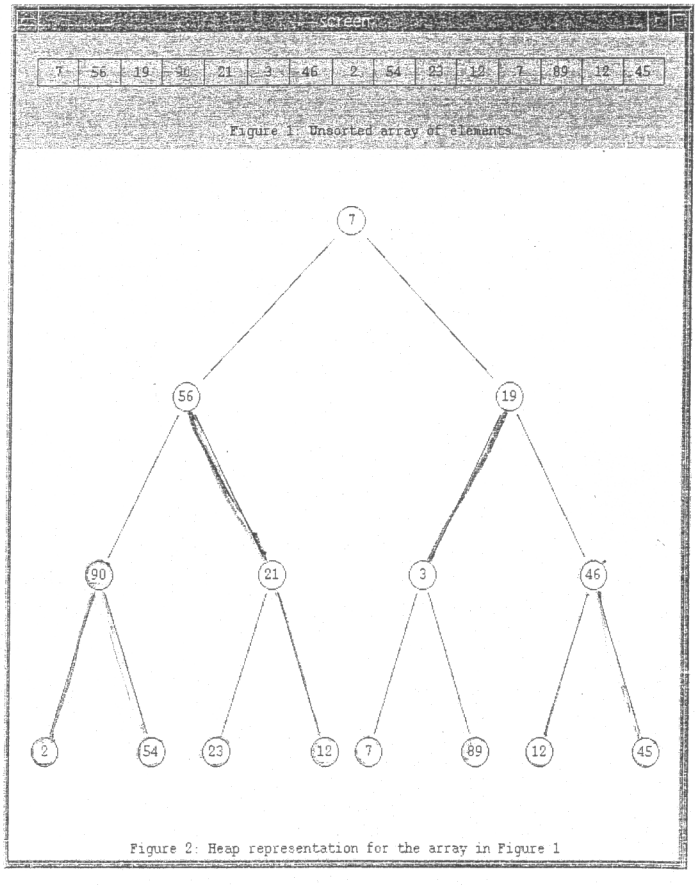
Figure 2: Heap representation for the array in Figure 1


screen
7 56 19 90 21 3 46 2 54 23 12 7 89 12 45
Figure 1: Unsorted array of elements
7
56
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7
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45
Figure 2: Heap representation for the array in Figure 1

The scientist has a lot of experience with ignorance and doubt and uncertainty, and this experience is of very great importance, I think. When a scientist doesn't know the answer to a problem, he is uncertain. And when he is pretty darn sure of what the result is going to be, he is still in some doubt. We have found it of paramount importance that in order to progress we must recognise our ignorance and leave room for doubt. Scientific knowledge is a body of statements of varying degrees of certainty - some most unsure, some nearly sure, but none absolutely certain.

Richard Feynman (cited in a letter to the Guardian)